Brain activity during deception: an fMRI study

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Deception is a derivative of truth

- Deception is an act **intended** to create a perception of reality different from the deceiver's

- Deception is **intentional negation** of subjective truth (St.Augustine) or distortion of the truth (Kant)

- In children, the ability to deceive increases with age and **inhibitory control** (Carlson 1998)

- **Does deception require inhibition of the truth?**

Physiological detection of deception

- **The Spanish Inquisition: "dry bread" test**

- **Voice Analysis: "Truster"
  http://www.telstarone.com/truster.htm**

- **Increased Eye Blink Rate (Fukuda 2001)**

- **Delayed Response Time (Seymour 2000)**

Physiological detection of deception: "the polygraph"

Multi-channel physiological recording (polygraph) is based on debated assumptions:

1. Deception induces specific and reproducible physiologic responses related to the autonomic arousal

*2.These responses can be reliably elicited by the investigator (Brett, Lancet 1986, Steinbrook NEJM 1992)*

Physiological detection of deception: ERP

- **ERP is a correlate of brain electrochemical activity. ERP has high temporal resolution**

- **The brain sources can not be uniquely localized**

- **P-3 wave appears in response to rare and meaningful stimuli with 300-1000 msec latency**

- **P-3 ERP analysis has been > 90% accurate in detection of simulated deception in the lab**

BOLD fMRI

- **Blood oxygenation level dependent (BOLD) fMRI has sufficient spatial and temporal resolution to study rCBF**

- **There are no reports on the use of fMRI to study deception**

- **We used event-related BOLD fMRI and the GKT to identify location of the changes in the rCBF during deception**

fMRI setup
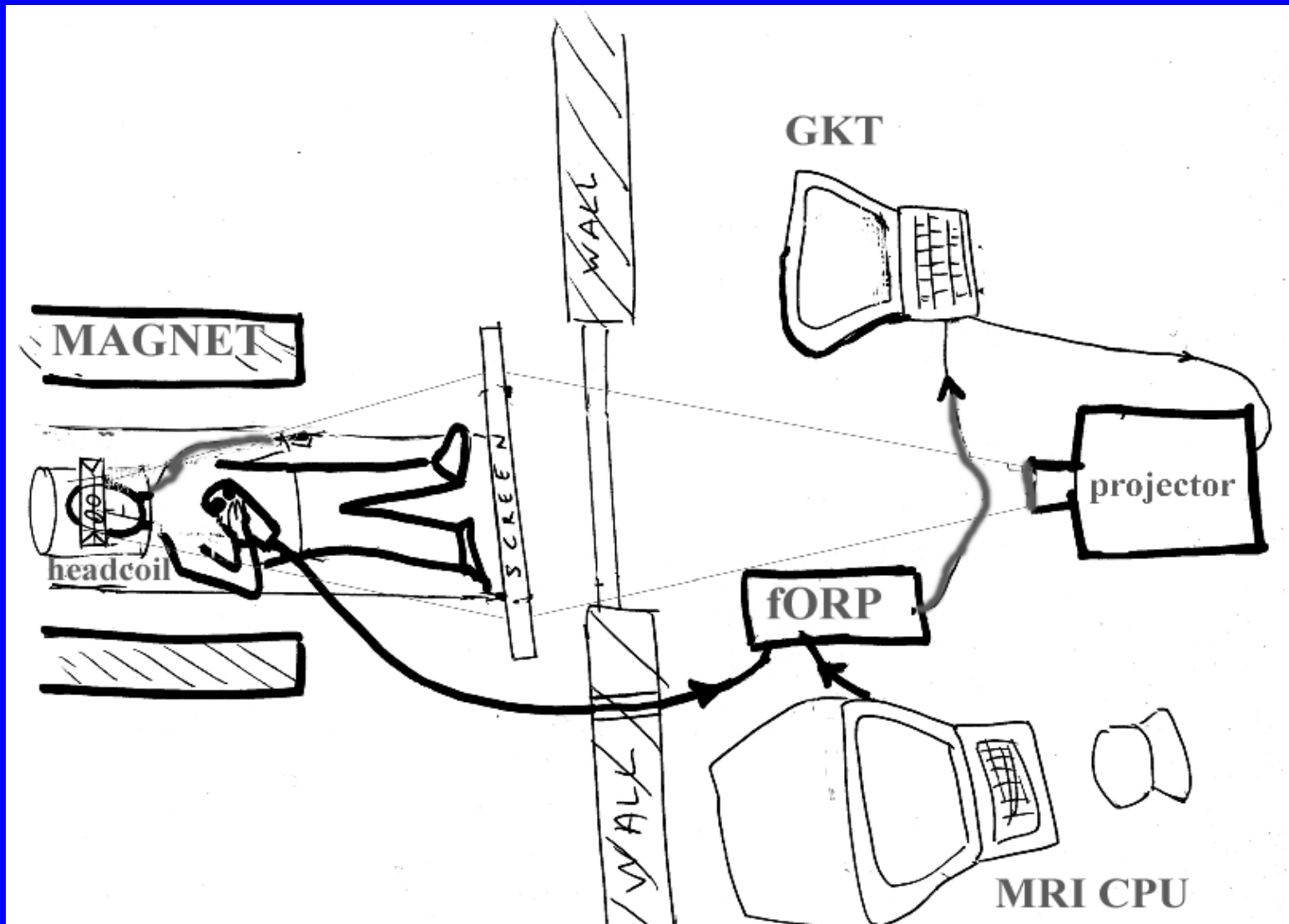
fORP: Fiber-optic response pad
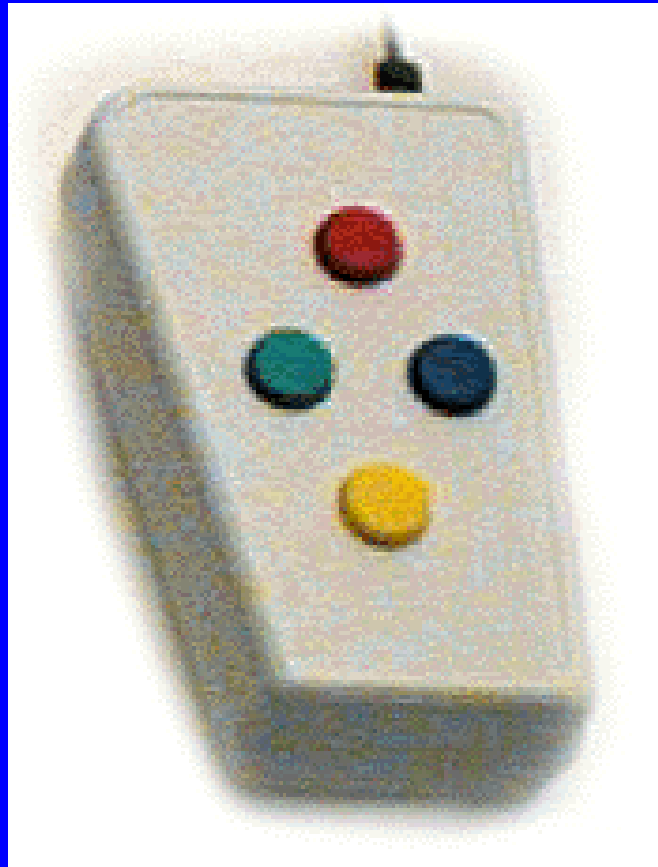
The Guilty Knowledge Test

- **Facilitates psychophysiological detection of the prior knowledge of crime details (Lykken 1958, 1991)**

- **Was adapted to model deception in polygraph and ERP research**

- **lab ≠ forensic. In the lab, GKT deception is "endorsed" - subject is instructed how to respond**

Hypotheses

1. The cognitive difference between lying and telling the truth has an rCBF correlate

2. Brain regions involved in response inhibition are differentially activated by the GKT

The GKT: Single Trial Mixed Design
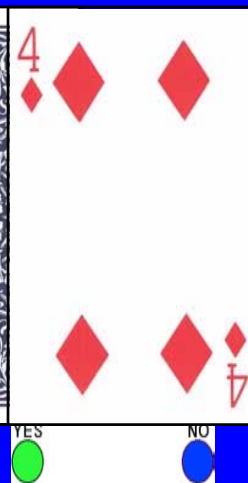
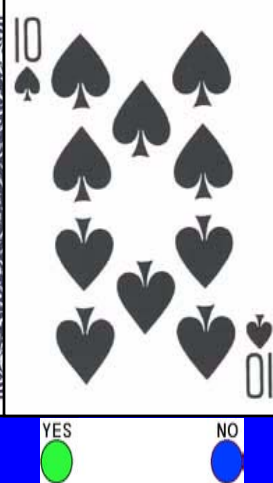3 s   12 s   3 sec   12 s   3s   12s   3s
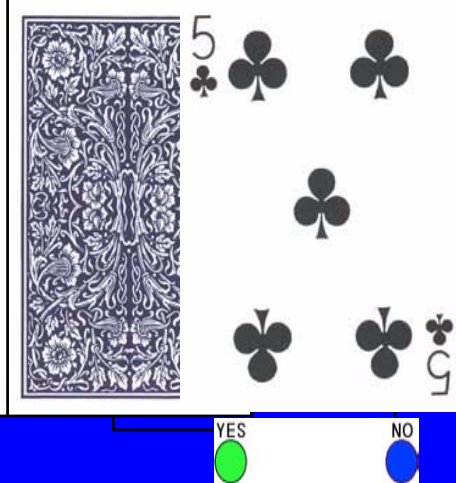

Do you have this card?

Do you have this card?

Is this Ten of Spades?

Do you have this card?

Truth

non-target

Control

Lie

Subjects

- **23 healthy right-handed participants**
- **11 men and 12 women**
- **22 to 50 years old (average 32)**
- **12-20 years of education(average 16)**
- **22 native English speakers**

Methods

- 4Tesla GE scanner. T1 localizer and multislice GR EPI, 21 slices, 5 mm thickness, no skip, TR = 3000, TE = 40 and effective voxel resolution of 3.75 x 3.75 x 4mm. 12x12x12 mm smoothing

- Using SPM99' with an IDL interface, within-subject contrasts between GLM regression coefficients were generated for the **main contrast: "Lie" Vs "Truth"** and the secondary contrasts: "Lie" Vs. "Control" and "Truth" Vs. "Control"

Methods 2: Second-level Analysis

- Second-level analysis: group SPM's using a random-effects model within SPM99 with the individual contrast maps. **The resulting SPM {t} map was transformed to the unit normal distribution SPM{Z}, thresholded at p < 0.01 and corrected for spatial extent at p<0.05, using the theory of gaussian fields as implemented in SPM99**

- Thresholded SPM was overlaid on a standard T1 template using MEDx

Methods 3: Honest and Restless Subjects Excluded!

- One subject excluded **for repeatedly telling the truth** on the GKT

- Four subjects excluded from analysis because their individual Z-maps contained non-anatomical curvilinear change in Z values, indicating a **motion artifact**

- **Final N** in the analysis - **18**

Methods 4: MNI to Talairach conversion

- MNI coordinates (SPM99 output) were converted into Talairach coordinates using a non-linear transform (www.mrc-cbu.cam.ac.uk/ Imaging/ mnispace.html) and anatomical and Brodmann areas determined from the Talairach atlas

- ROI: two-tailed t-tests assuming equal variance between the average GLM regression coefficient values for "Lie" and "Truth" for the frontal gyri and the occipital lobes

Results: "Lie" Vs. "Truth"
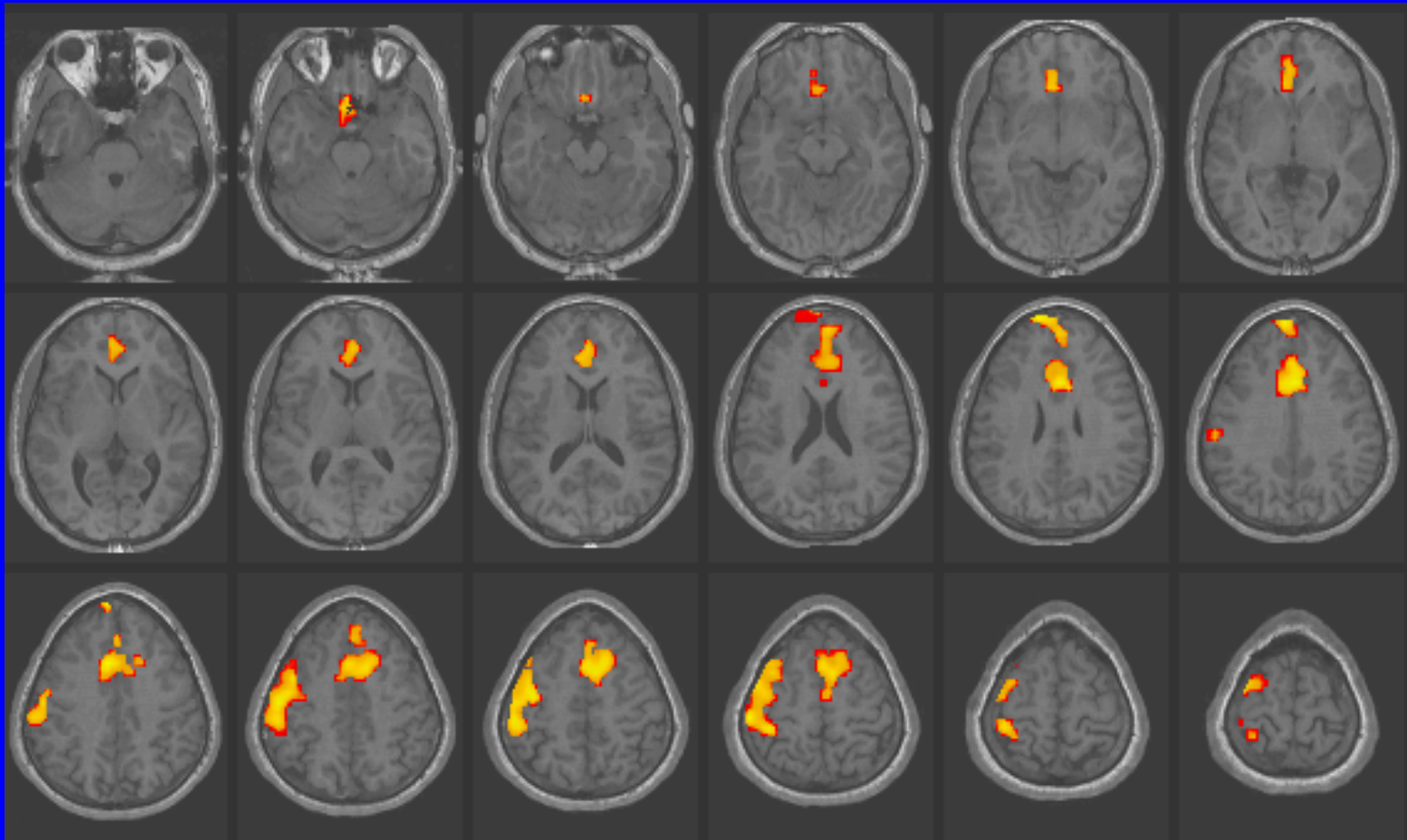
SPM (t) projected over standard template demonstrating significant increase in BOLD fMRI signal in the ACC, the medial right SFG and the superior left pre- and post- central gyrus thresholded at $p < 0.01$ and corrected for spatial extent at $p < 0.05$

. . . and at threshold p < 0.05
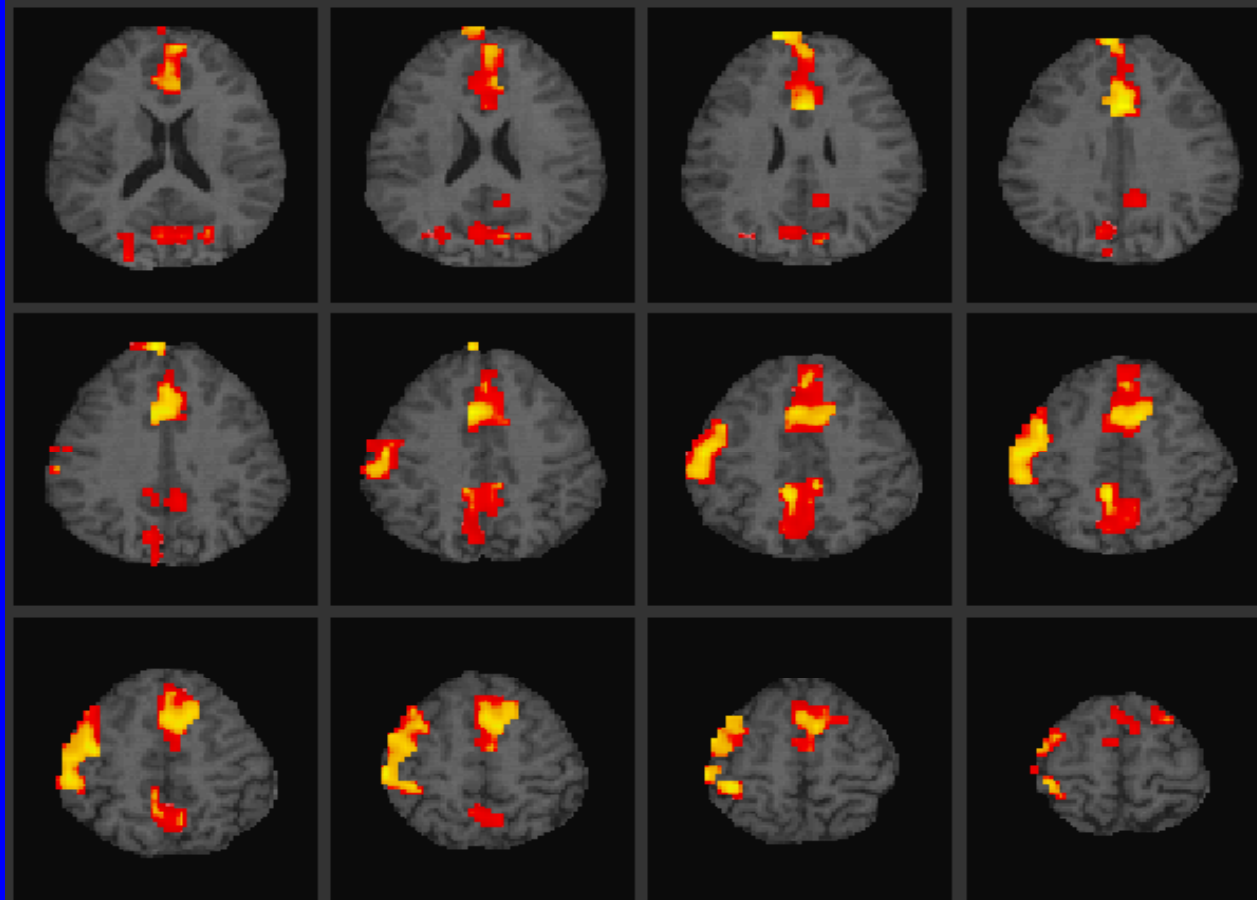
Results: Location of significant differences between "Lie" and "Truth" conditions

cluster size voxels	Z	Talairach Coordinates			BA	Gyrus
		x	y	z		
146	3.8	-1	16	29	24;32	**Anterior cingulate**
----	3.17	3	28	43	6;8	Right superior frontal
----	3.15	0	24	52	8	Superior frontal
91	3.58	-57	-23	41	1;2;3;40	**Left postcentral**
----	3.40	-54	-15	38	3;4;6	Left pre and postcentral
----	3.19	-50	-3	49	6	Left precentral

voxel level threshold T = 2.57, p < 0.001 uncorrected and 0.05 corrected for multiple comparisons, spatial extent threshold > 80 voxels

Results 3: Secondary Comparisons

- "Lie" Vs. "Control" and "Truth" Vs "Control" to determine whether the "Lie" Vs. "Truth" difference was found only in the main comparison

- Secondary comparisons did not overlap with the main contrast and did not show ACC or SFG activation

Results 4: Response Time and Anxiety

- No difference ($p < 0.4$) in median response time between "Lie" (1255 msec) and "Truth" (1204 msec)

- Median response time to "Control" (1462 msec) was longer than either "Lie" or"Truth" ($p<0.00003, 0.01$)

- No anxiety during or after the scan and no overlap with areas activated during Skin Conductance Response (Critchley 1999)

The GKT ≠ Go-No-Go, because "Control" minus "Truth" does not activate the inferior frontal gyrus?
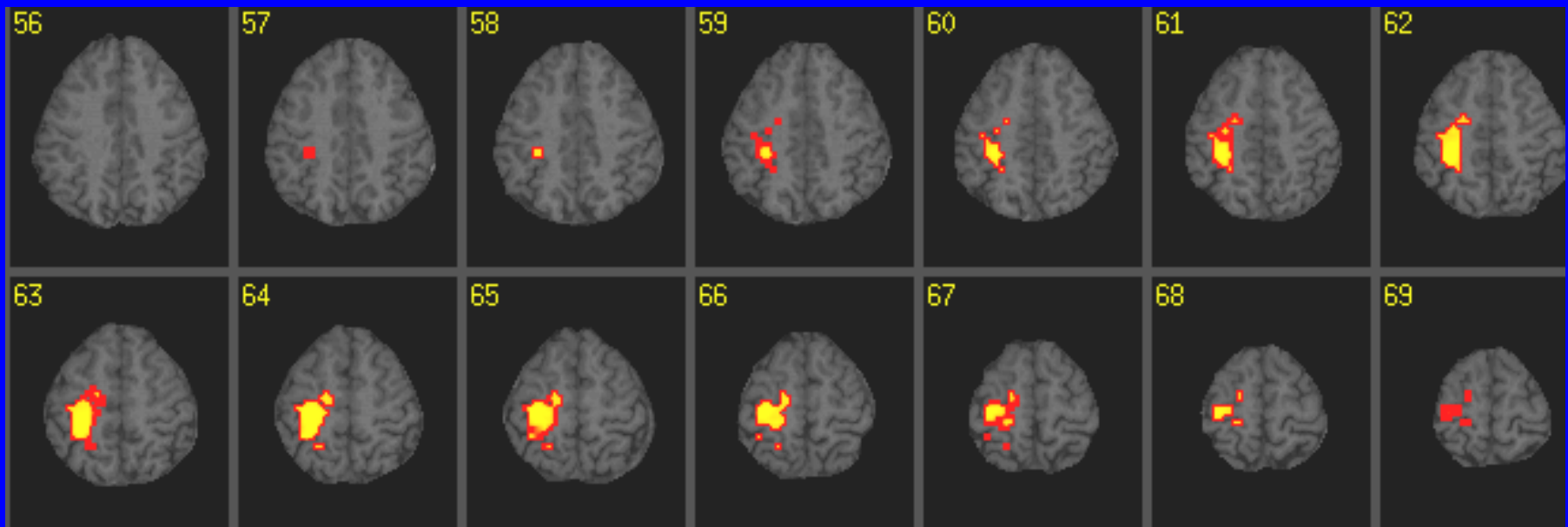
BA 4,3,7, Talairach 35; -30; 56.

Discussion 1

- *Hypothesis #1 is supported:* The cognitive difference between lying and telling the truth has an rCBF correlate

- *Is hypothesis #2 supported?* There is a partial overlap between activation during GKT deception and the GoNoGo. ACC and SMA activation has been reported in GoNoGo by some but not all (Rubia 2000, Konishi 1998,1999). Unlike GoNoGo in Konishi, the IFC has not been activated

Discussion 2

- Tasks activating the ACC involve: "inhibition of prepotent response, error monitoring and tasks with incompletely constrained responses" (Carter 1998, Barch 2000).

- GKT deception = response inhibition + error monitoring + decision making?

Conclusions

- **The group difference between deception and truth can be demonstrated at the cortical level with event-related BOLD fMRI**

- **Deception has a brain correlate unrelated to anxiety:** No limbic or memory activation with our GKT design

Conclusions - Future Research

Refinements in paradigm design and image analysis could increase the salience and the power of the simulated deception paradigms and establish an activation pattern **predictive of deception on an individual level**

pos

SPM{mip}
[0, 0, 0]

contrast(s)

SPM{T₁₇} → $\text{SPM}\{T_{17}\}$

Design matrix
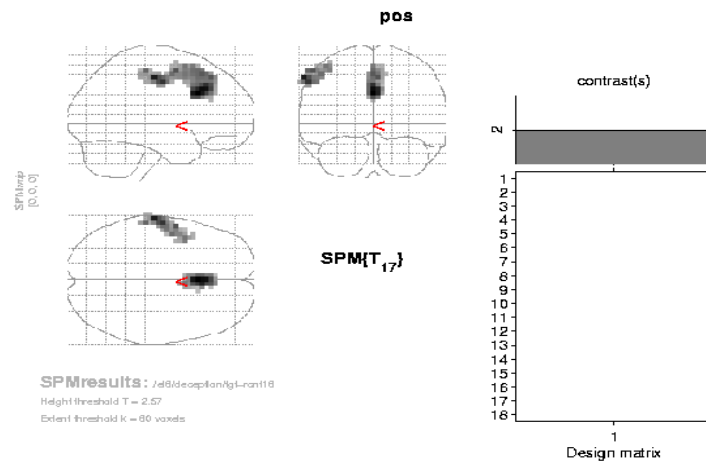
SPMresults: /d6/deception/lg1-ronf18
Height threshold T = 2.57
Extent threshold k = 80 voxels

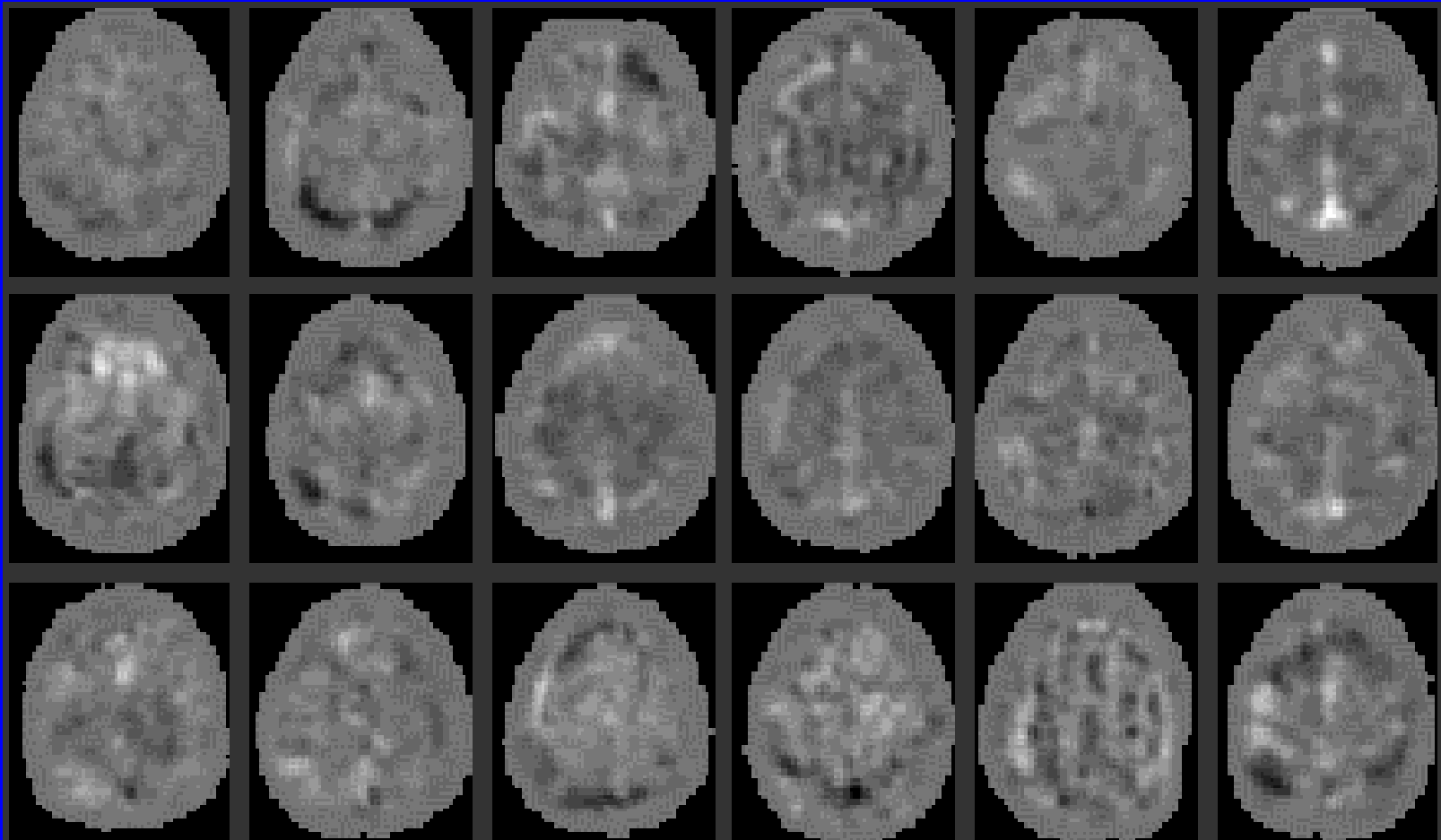**Statistics:** *volume summary (p-values corrected for entire volume)*

set-level		cluster-level			voxel-level				x,y,z {mm}
p	c	$p_{corrected}$	k_E	$p_{uncorrected}$	$p_{corrected}$	T	$(Z_\equiv)$	$p_{uncorrected}$	
0.002	2	0.002	146	0.000	0.992	4.86	(3.80)	0.000	0 20 32
					1.000	3.77	(3.17)	0.001	4 32 45
					1.000	3.74	(3.15)	0.001	0 24 52
		0.037	91	0.000	1.000	4.45	(3.58)	0.000	−64 −20 48
					1.000	4.15	(3.40)	0.000	−60 −12 44
					1.000	3.60	(3.19)	0.001	−56 0 56

table shows at most local maxima > 8.0mm apart per cluster

Height threshold: T = 2.57, p = 0.010 (1.000 corrected)	Degrees of freedom = [1.0, 17.0]
Extent threshold: k = 80 voxels, p = 0.001 (0.069 corrected)	Smoothness FWHM = 11.7 12.3 13.4 {mm} = 2.9 3.1 3.3 {voxels}
Expected voxels per cluster, <k> = 5.442	Search volume: S = 3906176 mm^3 = 61034 voxels = 1650.7 resels
Expected number of clusters, <c> = 0.07	Voxel size: [4.0, 4.0, 4.0] mm (1 resel = 29.86 voxels)

SPM99 (schroed): 00:17:29 − 20/03/2001

Individual SPM {T} maps

Maps of individual unthresholded BOLD signal amplitude GLM regression coefficient difference for "Lie" minus "Truth" at the ACC level
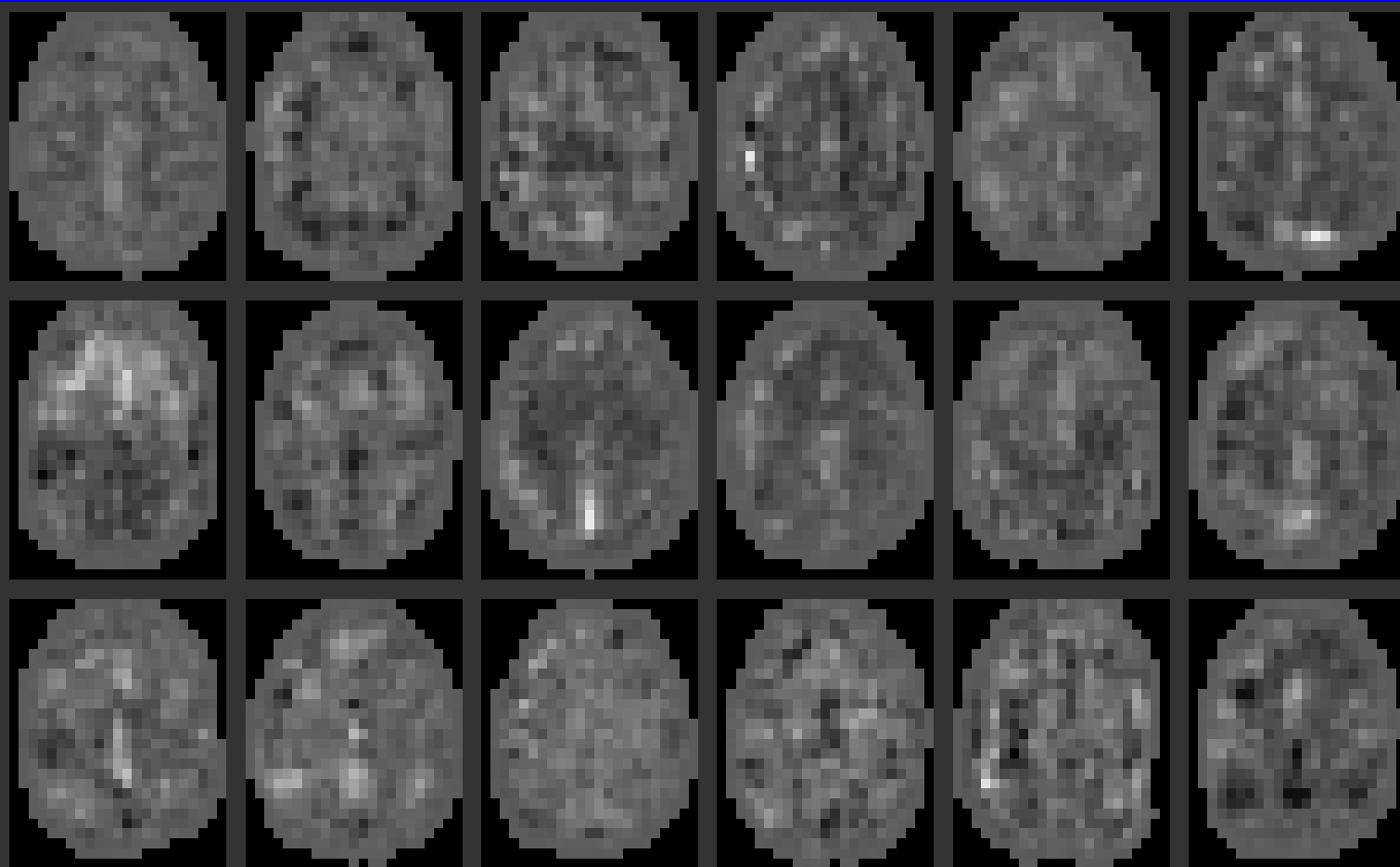
Results - ROI analysis

- bilateral ACC (right $p < 0.03$, left $p < 0.05$)
- left MFG ($p < 0.03$), right MFG ($p<0.9$)!
- bilateral SFG (right $p < 0.02$, left $p < 0.01$)
- Left orbital gyrus ($p < 0.03$)
- the difference in the precentral gyrus was not significant ($p < 0.13$)
- no difference between "Lie" and "Truth" in the occipital cortex ($p < 0.8$ and 0.5)